In the Specification

Page 1, second full paragraph

Prior Art

The applications of digital data circuits are continuously expanding. In the majority of cases the digital signal transmission presents significant advantages over analog signal transmission. The costs of high-speed data channels are reduced by the development of new transmission techniques. The width of the individual channels has become very inexpensive so that multiplexing of several low-rate signal circuits to form a single high-speed signal circuit is often the most economic solution. This has been implemented particularly in high speed rotary joints ~~high-rate revolving connectors~~.

Page 2, first full paragraph

A very important aspect not only in the application of contact-free high-rate circuits but of any electronic device is the electromagnetic compatibility. Electromagnetic emissions are most critical in wire-based circuits and in unshielded rotary joints ~~revolving connectors~~, but even transmitters, receivers and amplifiers in circuits based on optical fibers may emit electromagnetic fields.

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In correspondence with prior art optional signals and digital signals in particular are transmitted in the base band or in a modulated form, predominantly in the form of more or less steep-edged rectangular signal strings. These signal strings present a distinct wide line spectrum as a function of the respective coding. This spectrum may result in interfering radiations already in closed or shielded systems, particularly, however, in open systems such as rotating data transmission devices ~~revolving transmitters~~, which interfering radiation may exceed the limits defined in the common EMC standards. In this respect contact-less open transmission systems such as those employed for linear transmission or rotating ~~revolving~~ transmission are particularly problematic. Leakage

line systems are explicitly affected by this effect, too.

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The present invention is therefore based on the objective of configuring a digital transmission circuit, particularly a contact-free ~~revolving~~ rotating data transmission circuit, in such a way that the emitted noise level may be reduced in the sense of the current EMC standards, without a corresponding impairment of the quality in transmission.

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This problem is solved with the provisions defined in Claim 1. In accordance with the invention the transmitted line spectrum of the signal is spread by modulation of the transmission cycle in such a way that the gaps between the individual spectral lines are filled and hence the mean spectral power density is reduced. An inventive system consists of a transmitter in correspondence with prior art, which comprises a clock generator, as well as a ~~an additional~~ modulator unit which controls the transmitter or the clock generator thereof, ~~respectively,~~ or the transmitter output signal to an optional site in the transmission circuit in such a way that the spectrum will be spread. Such a control may be a phase or even frequency modulation, for instance. Amplitude-modulating or other modulating techniques are conceivable as well, however. Furthermore, a ~~an additional~~ controller is provided which provides the modulator unit with the modulation signal.

Page 3, third full paragraph

The invention is unambiguously distinguished from a modulation technique for improvement of the EMC characteristics of an integrated circuit, which is known from prior art from a publication by the company of IC Works, 3725 North First Street, San Jose, CA, U.S.A. of March 1997, entitled "Spread Spectrum Clock Generator". This prior art reference relates to the improvement of the EMC properties in computer boards, but not in transmission circuits.

Page 4, first full paragraph

Influence of spectral spreading on EMC characteristics

The general term "Electromagnetic Compatibility (EMC)" is hard to define. Here reference is made to the very general CISPR 11 standard which defines limits for the maximum emission of electromagnetic energy and which specifies the suitable measuring techniques. This standard determines a measurement of ~~emitted~~ maximum emissions in the frequency range of 30 MHz to 1 GHz. The emitted power is measured in 120 kHz steps with a bandwidth of 120 kHz. It is not definitely necessary in the application of a spectral spreading technique to have a uniformly distributed wide-band spectrum; what must be duly considered is only the fact that the same amount of energy is supplied to each 120 kHz range. This can be achieved with a wide-band signal or an individual narrow-band peak in this range. For the majority of applications the spreading of this spectrum in lines having a spacing of 120 kHz or a safety spacing of 100 kHz from each other constitutes the most inexpensive ~~inexpedient~~ solution. A further spreading of this spectrum requires the introduction of very small frequency variations in the data stream. In some applications, these modifications occur naturally, e. g. when "real data" such as video signals are ~~is~~ transmitted. However, provisions should be made to ensure that in extreme situations, e.g. when the video signal is deactivated and only digital zeros are transmitted, the spectrum is spread to a sufficient width so as to comply with the EMC specifications.

Page 5, second full paragraph

In accordance with the invention the conventional data coding is expediently applied ~~continued~~ for an optimization of the EMC characteristics.

Page 5, fourth full paragraph

In a particularly expedient embodiment of the invention the modulation unit is so configured that it subjects the cycle frequency of the clock generator of the transmitter to fre-

quency modulation in correspondence with the modulation signals of the controller. Such a configuration is particularly simple to implement in engineering terms by providing a VCO in the frequency-determining element of the clock generator, which varies the frequency of the clock generator as a function of the control voltage applied thereto. The control voltage of this VCO is predetermined by the controller. When the controller now furnishes a low-frequency signal ~~The~~ the frequency of the clock generator of the transmitter varies with the timing ~~cycle~~ of this signal, too, and hence it is frequency-modulated.

Page 5, fifth paragraph

Frequency modulation

Frequency modulation is the direct approach for spreading the spectrum. Serial standard transmission circuits such as TAXIchip® or Hot-Link® tolerate a static variation from the cycle frequency by ±0.1 %. To observe the limits set for quartz oscillator tolerances the maximum frequency deviation ~~variation~~ should be less than 10^{-4}. As the spreading of spectral lines does not furnish an advantage below 100 kHz, as has been set out in the foregoing, the minimum data rate f_{Dmin} for low-rate frequency shifts is as follows:

Page 6, second full paragraph

Phase modulation

Phase modulation is simply achieved by insertion of a controlled electrical delay into the carrier signal (or clock signal~~, respectively~~). A low frequency of phase modulation can be automatically controlled in timing by the receiver PLL but it does not result in a significant spreading of the spectrum. A very high frequency phase modulation produces the desired effect on the spectrum but its behavior is comparable to an additional synchronization interference on the receiver input.

Page 6, fourth paragraph

Modulation of the data stream

In accordance with the present invention, the spectrum can also be spread by modulating the transmitter output signal (or the data stream~~, respectively~~). The modulation or modification of the transmitter output signal (or the data stream~~, respectively~~) as such presents a great advantage over the modification of the transmitter carrier signal (or the transmitter data cycle signal, respectively). A modification in the transmitter as such is not required. The transmitter output signal (or the data stream, respectively) can be modified anywhere in the transmission circuit. Hence this system does not demand any modification of the transmitter design, which allows for low development costs and a smooth integration into existing designs.

Page 8, first full paragraph

Furthermore, the phase shift can be expediently implemented by a timing recovery ~~clock regeneration~~ technique.

Page 8, third full paragraph

In correspondence with another expedient embodiment of the invention a controller unit is provided in the receiver which controls the clock generator of the receiver in synchrony with the modulation of the transmitter. This synchronization can be optionally performed via a signal which is jointly available to the transmitter and receiver sides, such as the line ~~network~~ frequency.

Page 8, fifth full paragraph

In ~~An~~ another expedient embodiment of the invention an additional signal is transmitted in parallel with the transmission circuit between the transmitter and receiver sides for controlling the modulation. On account of this additional signal now a demodulation can

be performed in the receiver, which is synchronized with the modulation in the transmitter.

Page 11, third full paragraph

Fig. 25 is a view of a 200 MBaud 1010-PCM signal spectrum with pseudo-random coding from 9 to 1 GHz.

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What appears are ~~is~~ only odd harmonics with a linearly decreasing amplitude. Even harmonics occur only if the signal is non-symmetrical. When the signal has other patterns with wider time intervals of zeros and ones, like the signal in Fig. 6, side bands appear in the spectrum with offsets by multiples of the frequency components of these longer time intervals. This leads from a plain needle spectrum to a multiply diversified spectrum such as that illustrated in Fig. 7.

Page 14, third paragraph

Pseudo-random patterns

A data stream including a random succession of zeros and ones results in a very homogeneous spectral distribution. In theory, an unlimited random succession would result in a perfect spreading spectrum having a constant spectral power density. It is disadvantageous ~~inexpedient~~ that such a data stream cannot contain the desired information. In an approach to a solution to this problem it is possible to employ deterministic pseudo-random patterns. These patterns consist of a predetermined reproducible string of bits. As a rule, the length of these patterns is determined. These patterns are referred to as pseudo-random patterns because; at the first glance, they look like a random string even though they yet present a determined succession and can be predicted. A genuine random succession can never be predicted.

Page 16, second full paragraph

Static patterns

The mostly serial transmitters operate on a blank character if there is no data to be transmitted. This blank is an unambiguous pattern which enables the identification "no data" and furthermore permits the synchronization of the receiver with the transmitter clock signal. Only one kind of blank pattern is usually present. If over prolonged periods of time no data is transmitted only this pattern is transmitted via the circuit. It presents the same length as a standard data word and has therefore a comparatively high lower frequency and a spacing of the spectral lines which derives from the equation (5). Such patterns do usually not present a straight distribution of their spectral lines. Consequently, a high-speed data link may display excellent EMC characteristics when real data is transmitted. But as soon as the transmission is terminated and a blank is transmitted the EMC characteristics are strongly impaired. These static patterns are the most inexpedient case of electromagnetic emission or transmission~~, respectively~~. If a transmission of these patterns cannot be avoided over a prolonged period of time the EMC measurements should be made under these conditions.

Page 17, first full paragraph

Inventive method of spreading the bandwidth

As has been described in the foregoing, there are different approaches for spreading the spectrum. The best effect on the electromagnetic emission is achieved when at least two methods are applied which complement ~~complete~~ each other. A very good combination is a pseudo noise data coding together with some kind of modulation of the data variation in time. The data variation in time can be modulated in different ways. One approach is the modification of the original data cycle signal at the transmitter end. Another way is the modification of the variation in time of the data stream as such.

Page 17, second full paragraph

Data coding

As has been set out in the foregoing, the data stream should have the appearance of a random string for optimization of the EMC characteristics. Real data very often displays random characteristics. In measuring signals or video image signals a certain noise always occurs which contributes also the random characteristics. In other cases the coding of the data stream with a random string would furnish a desired result. This coding is very easy to implement. When data is transmitted in large blocks each block may be subjected with a given random string to an exclusive-ORing process (Fig. 13). Now the transmitted signal has the appearance of a random signal. Even in the worst case of a string of zeros or ones the signal looks like a random signal.

Page 18, third full paragraph

For achievement of an improvement for lower data rates in case of frequency modulation the cycle must be shifted by more than the permissible 10^{-4}. This can be achieved by synchronous shifting of the transmitter and receiver cycle. For execution of this shift a low-frequency message transmission must be provided between the transmitter and the receiver. Such an information can be transmitted via an additional low-frequency line or, in the case of rotary joints ~~revolving connectors~~, through a conventional slip-ring circuit. In such a case noise and bandwidth are not critical. Another approach is the application of some signals which are already jointly available, like in the case of an AC energy circuit for modulating the synchrony between the transmitter and receiver cycles. Hence an additional signal is not required.

Page 20, third full paragraph

On account of the very small additional delays the signal behaves like a signal with additional low synchronizing interferences (jitters) (cf Fig. 20). This additional jittering presents two spectral components which must be considered. Initially, the high-frequency modulation behaves like a real jitter. It takes an influence on the link properties. For

contact-free rotary joints ~~revolving connectors~~, however, which present a 5% jitter, an additional modulation jittering of 5% is acceptable. The majority of digital link receivers accept 20% jittering without any impairment. Secondly, the low-frequency component of the modulation generator is so selected that a period is slightly shorter than the period of the integration of the EMC measurement. For measurements in compliance with CISPR lithe period lasts for 10 ms. Hence the modulation frequency should be higher than 100 Hz. This low frequency is eliminated by all receiver PLLs.